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Pup production of non-Sable Island grey seals, in 2004

Production de jeunes phoques gris en dehors de l'Île de Sable en 2004

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ABSTRACT

Northwest Atlantic grey seals form a single stock, but are often considered as two groups for management purposes, the Sable Island and Gulf of St Lawrence herds, named for the location of the main pupping locales. In 2004, visual strip transect surveys were flown over the whelping patches on the ice in the Gulf of St. Lawrence and counts were completed at islands in the Gulf and along the Nova Scotia Eastern Shore. Pup production estimate for visual strip transect surveys, after correcting for timing of births, was 10,145 (SE=1,930) from surveys flown on 21, 22 and 23 January. Surveys flown on 30 and 31 January and 2 February produced an estimate, corrected for timing of births of 13,819 (SE=1,565). Another 3,204 (SE=76.8) births were estimated on the islands, after correcting for timing of births. Total Gulf and Nova Scotia Eastern Shore pup production in 2004 is estimated at 15,900 (SE=1,200) animals.

RÉSUMÉ

Les phoques gris du Nord-Ouest de l'Atlantique ne constituent qu'un seul stock, mais, aux fins de gestion, ils sont souvent classés en deux groupes nommés d'après l'emplacement de leur principal lieu de mise bas. Le plus grand groupe met bas sur l'île de Sable, à 290 km à l'est de Halifax (Nouvelle-Écosse). Le deuxième groupe (désigné sous le nom de "autre que l'île de Sable" ou "Golfe") met bas principalement sur la banquise dans le Sud du golfe du Saint-Laurent, et des sous groupes mettent bas sur de petites îles du Sud du golfe du Saint-Laurent et le long de la côte Est de la Nouvelle-Écosse. En 2004, des relevés aériens visuels par bande ont été complétés pour les concentrations de mise bas sur la glace du golfe du Saint-Laurent et des décomptes ont été réalisés sur des îles du golfe et de la côte est de la Nouvelle-Écosse. L'estimation de production de jeunes pour les relevés visuels en bande, après correction pour la distribution temporelle des naissances, était de 10 145 (erreur-type=1 930) pour les relevés survolés les 21, 22 et 23 janvier. Les relevés complétés les 30 et 31 janvier et 2 février ont produit une estimation corrigée pour la distribution temporelle des naissances de 13 819 (erreur-type=1 565). A ces nombres, il faut ajouter 3 204 (erreur-type=76.8) naissances, estimé des naissances sur les îles, après correction pour la distribution temporelle des naissances. La production totale de jeunes pour le golfe et la côte est de la Nouvelle-Écosse en 2004 est estimée à 15 900 (erreur-type=1 200) animaux.

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INTRODUCTION

The Northwest Atlantic grey seal (*Halichoerus grypus*) forms a single population (Boskovic et al. 1996). However, for management considerations the population is normally divided into two groups; a Sable Island component and a non-Sable Island component. Using pup production as an index of population size and trends, pup production on Sable Island has increased rapidly since the 1970's, from less than 2,000 animals in 1975 to over 25,000 pups in 1997 (Bowen et al. 2003) for an annual rate of increase of 12.8%.

Less is known about the non-Sable island component of the Northwest Atlantic grey seal. This component, also referred to as Gulf grey seals, consists of animals that whelp primarily on the drifting pack ice in Northumberland Strait and off the west coast of Cape Breton Island (Fig. 1). Smaller whelping colonies are found on Amet Island, Deadman Island and along the Nova Scotia eastern shore (Mansfield and Beck 1977). A new colony was discovered on Hay Island in 1993 by J. Conway (DFO-Halifax).

Using a Petersen mark-recapture model, non Sable-Island pup production increased from 5,436 (SE=672) in 1984, to between 8,116 (SE=846) and 10,437 (SE=3,164) for the period 1989-90 (Hammill et al.1998). Aerial surveys flown in 1996 resulted in a pup production estimate of 11,100 (SE=1,300), but subsequent surveys indicated a decline in pup production to 7,300(SE=800) in 1997 and 6,100 (SE=900) in 2000 (Hammill et al. submitted).

Here we provide a new estimate of Non-Sable Island pup production from aerial surveys and island counts completed in January-February 2004.

MATERIAL AND METHODS

The non-Sable Island component whelps from late December through early February on some small islands in the Gulf of St. Lawrence and along the Nova Scotia Eastern Shore. However, the majority of pups are born on drifting pack ice in the southern Gulf of St. Lawrence (Fig 1). Ice breeding grey seals normally prefer medium sized floes (100-500 m across) of white or thin white ice, 15-70 cm thick. Whelping patches are often initially located in the Northumberland Strait

between Charlottetown in the west and Cape George in the east. Animals have not been located west of this area. Overall ice drift occurs in a west to east direction, but short term changes can occur according to tidal changes (east to west) and wind action. In some years, strong northerly winds push seals into St George's Bay, while in others, the ice may be pushed rapidly out of the southern gulf, where it exits via Cabot Strait (Fig. 1).

Reconnaissance surveys

Reconnaissance aerial surveys were flown at an altitude of 152 m (500 feet) from a helicopter during January 2004 in Northumberland Strait, and along the coast of Cape Breton Island.

Ice drift was monitored by following the movement of VHF transmitters that were deployed on the ice.

Birth ogive

Non-Sable Island Northwest Atlantic grey seals begin pupping on the islands in December and births continue until early February. The majority of births, particularly of ice breeding animals occur in January. Aerial survey estimates must be corrected to account for births that may occur after the strip-transect surveys are flown. This is done by modelling the distribution of births over the period of the survey. The model assumes that births follow a Normal distribution. It uses the change in the proportion of pups of different ages as the season advances to develop the birthing ogive (details described in Stenson et al. 2003). Only the first three stages are used in Normal model. Estimates of the number of pups in each concentration can then be corrected for pups born after the survey was flown by:

$$N_i = N_{uncor} / P_i \qquad (1)$$

where:

N_{uncor} = the uncorrected estimate for survey i;

P_i = the proportion estimated to have been born prior to survey i.

The estimates of N_{uncor} and P_i are independent and therefore the error variance of the quotient is given by (Mood *et al.* 1974):

$$V_i = N_{uncor}^2 \times V_p / P_i^4 + V_n / P_i^2 \quad (2)$$

where:

V_p = the variance in the proportion estimated to have been present prior to survey i;

V_n = the variance in the uncorrected estimate for survey I.

In order to do this, pups were assigned to one of 5 distinct age related categories based on a combination of morphometric and pelage features to model the distribution of births (Bowen et al. 2003). These categories were as follows: We used the stage durations for male pups.

Stage 1- animals very thin, movements uncoordinated, and the fur has a yellowish hue to it from the placental fluids (Mean duration=3.4 days, SE=0.91);

Stage 2- animals are thin, although they are beginning to show signs of fattening, a distinct neck is still visible, movements are more coordinated and the pelage no longer has a yellowish hue to it (Mean duration=4.4 days, SE =1.29;

Stage 3- the fur is white in colour and the animals have become so fat that a distinct neck is no longer discernable (Mean duration=12.1 days, SE =2.77).

Stage 4- Lanugo is being shed from any part of the body, except the face. (Mean duration=7.0 days, SE =2.3).

Stage 5- Lanugo completely shed from the body, or isolate tufts remaining, that do not account for more than 5 cm.

The study area was repeatedly surveyed and the change in the proportion of pups in each of the age dependent categories was noted.

Strip transect surveys

Visual strip transect surveys were flown at an altitude of 61 m by helicopter to estimate the number of pups on the ice. Observers seated in the left and right rear seats counted all seals within a measured 50 m strip on each side of the aircraft. The strip was delimited by placing tape marks on the windows while hovering at an altitude of 61 m over a measured distance marked out on the ice. Tape marks were also placed on the window to denote the horizon and the outside of the helicopter skid to aid the observer to maintain a constant position. Following the survey, strip widths were checked again to confirm the areas surveyed.

The data were analysed using the methods outlined in Hammill et al (1992). Survey strata were defined based on homogeneous transect spacing. For each stratum a weighting factor k_i was calculated as:

$$k_i = S_i / W_i \tag{3}$$

where S_i is the transect spacing (km) for the i^{th} group and W_i is the transect width (km) for the i^{th} stratum.

The estimated number of pups for the i^{th} stratum is given by:

$$N_i = k_i \left[\sum_{j=1}^{J_i} x_j \right] \tag{4}$$

where x_j is the number of seals counted on a transect and J_i is the number of transects in the i^{th} stratum.

The error variance was calculated based on the serial difference between transects (Cochran 1977; Kingsley et al. 1985) using:

$$V_i = \frac{k_i(k_i - 1)J_i}{2(J_i - 1)} \sum_{j=1}^{J_i - 1} (x_j - x_{j+1})^2 \tag{5}$$

If transect spacing changed the estimate of the number of animals became:

$$N_i = k_i \left[x_{i1}/2 + \sum_{j=2}^{J_i - 1} x_{ij} + x_{iJ_i}/2 \right] \tag{6}$$

and the variance estimate became:

$$V_i = \frac{k_i(k_i-1)}{2}\sum_{j=1}^{J_i-1}(x_j - x_{j+1})^2 \qquad (7)$$

The estimate for the total population and its variance estimate became:

$$N = \sum_{i=1}^{I} N_i \qquad (8)$$

$$V = \sum_{i=1}^{I} V_i \qquad (9)$$

where *I* is the number of strata.

Island counts

Pupping also occurs on several islands in the area. These were counted using several different techniques. At Amet Island, animals pup on the narrow beaches and on the ice that is caught on the reefs around the island. A total count was obtained by standing on top of the island, which is about 20 feet above sea level and counting animals around the island. At Henry Island, the beaches are also extremely narrow, and most pupping occurs in a small area on the south and southwest sides. These animals were counted from the air by helicopter hovering at 20 m and moving along the beach about 100 m offshore. At Deadman Island, pupping occurs on two sides of island. The helicopter landed at this site, and a counter walked along the south side then the north, from one end of the island to the other and back. Thus each counter obtained two counts of the number of pups on the beach. The final count was the average of the four counts. At Hay Island, vertical poles were set in the ground at 50 m intervals, setting up a series of transects along the island. Counters moved from one end of the island to the other and back. The count for the transect was the average of the two counts. These were summed over all transects. At Camp and White Islands and Bowen's Ledge, all pups were tagged to provide a total count.

RESULTS

Stage surveys were completed at Amet and Henry Islands and in Northumberland Strait between December 2003 and February 2004 (Table 1). Visual strip transect surveys were flown the 21, 22, 23, 30 and 31 January and the 2 February. Ice movement was monitored by following the change in position of a VHF transmitter in Northumberland Strait.

The flights conducted on 21,22 and 23 January form a single survey of the area (Fig. 2; Table 2). A total of 410 pups were counted on 52 transects resulting in an estimate of 7,944 (SE=1,333). Correcting for the estimated proportion of pups on the ice at the time of the survey (P_i=0.78, SE=0.07) results in an estimate of 10,145 (SE=1,930) pups for Northumberland Strait.

Flights completed on 30, 31 January and 2 February form a second complete survey (Fig. 3; Tables 3, 4). A total of 32 north-south transects were flown on the 30, 31 January survey. When plotted, parts of some lines flown on 30 January, overlapped with east-west lines flown on 2 February. The stratum limit was established at 46 degrees north, and any sightings of pups seen north of this boundary on the 30 January survey were excluded. Transect spacing on the 30, 31 January survey was one minute of longitude. A total of 889 pups were counted resulting in an estimate of 11,472 (SE=1,358) pups. Taking into account the proportion of pups on the ice at the time of the survey (P_i=0.998, SE=0.004), results in an estimate of 11,495 (SE=1,360) pups.

On 2 February, 10 east-west transects spaced two minutes of latitude apart were flown. A total of 77 animals were seen on transect, resulting in a total estimate of 2,854 (SE=775) pups. By 2 February, pupping had essentially finished (P_i=0.9996, SE=0.0008), so no correction was included in the 2 February survey. Combining the 30 January and 2 February surveys, results in an estimated pup production of 13,819 (SE=1,565) animals.

Pups counts were also conducted at Amet, Henry, Deadman, Hay, White and Camp Islands and Bowen's Ledge (Fig. 1; Table 5). A total of 3,204 (SE=76.8) pups were counted on the different Islands. This represents a minimum

count, since Deadman and Hay Island and the islands along the Eastern shore were only visited once, which does not allow development of a correction curve. Combining the strip transect survey and island count data results in a total pup production of 13,349 (SE=1930) from the 21-23 January survey and 17,554 (SE=1566). Combining the results from the two surveys results in a grey seal pup production estimate of 15,886 (SE=1,216) in 2004. Rounded to the nearest 100, this becomes 15,900 (SE=1,200).

DISCUSSION

Pup production in pack ice pinnipeds is difficult to determine because whelping often occurs in remote areas, whelping concentrations are scattered and births are staggered. Aerial surveys have been used successfully to determine pup production in Northwest Atlantic harp and hooded seal populations by using a combination of extensive aerial reconnaissance and correcting for the fraction of pups not on the ice at the time the survey was flown (Bowen et al. 1987; Hammill et al. 1992; Stenson et al 1993, 2003).

In the Gulf, grey seals differ from harp and hooded seals in that females whelp in small, widely dispersed concentrations on very thin and less stable ice. Also, the timing of whelping, during the middle of winter, makes for short flying days and often poor flying conditions. Furthermore, whelping extends for a longer period of time compared to the other species, beginning in late December and continuing until mid February.

Pup production on the pack ice in the southern Gulf of St. Lawrence increased from 6,900 in the mid-1980s to a peak of around 11,100 animals in 1996. Since then, pup production declined to 6,100 animals by 2000, before showing another increase in 2004 to 15,900 (SE=1,200) (Table 6). The reasons for this fluctuation in pup production are not clear. It is also not clear whether these changes represent multi-year trends or result from inter-annual fluctuations in natural mortality or animals moving to other sites to pup. Without more frequent surveys it will not be possible to tease this out.

There is no evidence suggesting that animals whelped elsewhere in the southern Gulf. Reports of land-based colonies other than those already known were not received. Other areas such as Baie des Chaleurs have been searched in previous years as soon as suitable ice formed (e.g. 9 February 1997), but no seals were seen. Also, no reports of large numbers of seals in non-traditional areas (e.g. south coast of Newfoundland) have been received. Grey seals movements from satellite tracking over the last decade do not reveal the use of areas for whelping that were not covered by reconnaissance flights (Goulet et al. 2001), but over-wintering off the New Brunswick coast of satellite transmitter equipped grey seals during January 2005 would suggest that this needs to be monitored in future surveys, particularly during mild winters.

Some correction to take into account pups not born at the time the survey was flown was required. The January 21, 22, and 23 surveys required the largest correction with an estimated proportion of 0.78 (SE=0.07) of the pups present. Births were almost complete by the time the 30, 31 January and 2 February surveys were flown resulting in little or no correction. The assumption that grey seal births follow a Normal distribution and applying this distribution to correct for births is one possible approach that has been successfully applied to harp seals (Stenson et al. 2003). Bowen et al. (2003) also developed a discrete version of an earlier approach that examined the fit of the stage data to a Weinbull, Gamma or Log-logistic distribution (Bowen et al. 1987). To examine possible differences in predicted proportion of pups present on the ice, we also ran the stage data using the approach developed by Bowen et al. (2003). The estimated proportions of pups on the ice at the time the surveys were flown were very similar between the two methods (Table 7). Total counts corrected for births on Henry Island using a Log-Logistic distribution were 101 (SE=12.5) animals compared to 103 (SE=4.5) using the Normal model. Survey estimates on the ice adjusted using a Gamma distribution were 9,583 (SE=1,896) and 14,535 (SE=1,397) for the 21, 22, 23 January and the 30, 31 January-2 February surveys respectively. Adding in the island counts results in pup production estimates of 12,787 (SE=1,898) and 17,739 (SE=1,602) for the first and second surveys respectively. These are similar to the

estimates of 13,349 (SE=1,930) and 17,554 (SE=1,566) obtained by fitting the stage data to a Normal distribution.

The Sable Island and Gulf grey seal colonies have had very different population trajectories. These differences likely result from the higher culling and scientific harvests in the Gulf (Stobo and Zwanenburg 1990; Hammill et al. 1998), and the higher mortality rates experienced by animals in the Gulf of St. Lawrence. Pup production in the Gulf appears to have fluctuated substantially between surveys. Without a more regular and frequent survey schedule, it will not be possible to determine the factors responsible for these inter-annual changes, whether they result from changes in mortality, movements to other regions or a combination of both. This variability and potential uncertainty in pup production underlines the need for caution in any management activities applied to this group.

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Table 1. Stage data collected at Amet, and Henry Islands and on the ice in Northumberland Strait between December 2003 and February 2004.

Date	Location	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Total
12-21-2003	Amet Island	22	37	61	9	0	129
1-12-2004	Amet Island	26	42	5	0	0	73
1-23-2004	Amet Island	3	46	146	11	0	206
Total							408
1-12-2004	Henry Island	23	1	0	0	0	24
1-24-2004	Henry Island	11	83	6	0	0	100
1-29-2004	Henry Island	1	23	41	2	0	67
Total							191
1-12-2004	Ice[1]	56	2	0	0	0	58
1-21-2004	Ice[1]	93	336	0	0	0	429
1-24-2004	Ice[1]	185	455	93	0	0	733
1-29-2004	Ice[1]	64	390	663	9	0	1126
2-3-2004	Ice[1]	1	24	354	65	4	448
2-9-2004	Ice[1]	4	30	610	290	92	1026
Total							3820

[1] Northumberland Strait

Table 2. Number of pups counted on north-south transects during visual surveys of Northumberland Strait during 21, 22 and 23 January 2004. Transect spacing was 1.5 minutes of longitude.

Date	Transect	Latitude start deg/min	Latitude stop deg/min	Longitude deg/min	Total pups
22/01/2004	1	45 46	45 41	61 32.5	2
22/01/2004	2	45 42	45 54	61 34	8
22/01/2004	3	45 41	45 56	61 35.5	3
22/01/2004	4	45 54	45 41	61 37	41
22/01/2004	5	45 52	45 41	61 38.5	4
22/01/2004	6	45 40	45 49	61 40	19
22/01/2004	7	45 39	45 51	61 41.5	5
22/01/2004	8	45 50	45 41	61 43	41
22/01/2004	9	45 50	45 40	61 44.5	17
22/01/2004	10	45 39	45 50	61 46	12
22/01/2004	11	45 39	45 49	61 47.5	7
22/01/2004	12	45 48	45 39	61 49	4
22/01/2004	13	45 49	45 40	61 50.5	5
22/01/2004	14	45 41	45 53	61 52	0
22/01/2004	15	45 43	45 54	61 53.5	0
22/01/2004	16	45 55	45 49	61 55	6
22/01/2004	17	45 55	45 52	61 56.5	4
22/01/2004	18	45 52	45 55	61 58	0
22/01/2004	19	45 53	45 55	61 59.5	1
22/01/2004	20	45 56	45 52	62 01	0
22/01/2004	21	45 57	45 52	62 02.5	0
22/01/2004	22	45 51	45 57	62 04	3
22/01/2004	23	45 50	45 58	62 05.5	8
22/01/2004	24	45 58	45 49	62 07	16
22/01/2004	25	45 47	46 00	62 08.5	22
22/01/2004	26	45 47	45 58	62 10	36
22/01/2004	27	45 59	45 46	62 11.5	22
22/01/2004	28	45 58	45 46	62 13	4
22/01/2004	29	45 45	45 58	62 14.5	4
22/01/2004	30	45 45	45 56	62 16	3
22/01/2004	31	45 58	45 43	62 17.5	3
21/01/2004	32	45 45	45 54	62 19	0
22/01/2004	33	45 42	45 56	62 20.5	0
21/01/2004	34	45 55	45 44	62 22	1
22/01/2004	35	45 57	45 41	62 23.5	0
21/01/2004	36	45 44	45 54	62 25	1
22/01/2004	37	45 41	45 56	62 26.5	0
21/01/2004	38	45 54	45 44	62 28	11

Table 2. (continued)

Date	Transect	Latitude start deg/min	Latitude stop deg/min	Longitude deg/min	Total pups
22/01/2004	39	45 56	45 40	62 29.5	12
21/01/2004	40	45 47	45 56	62 31	8
22/01/2004	41	45 39	45 57	62 32.5	41
21/01/2004	42	45 54	45 48	62 34	4
22/01/2004	43	45 57	45 41	62 35.5	26
21/01/2004	44	45 47	45 55	62 37	3
21/01/2004	45	45 55	45 46	62 38.5	0
23/01/2004	46	45 57	45 45	62 40	1
21/01/2004	47	45 47	45 53	62 41.5	0
23/01/2004	48	45 45	45 57	62 43	0
21/01/2004	49	45 52	45 46	62 44.5	0
23/01/2004	50	45 57	45 47	62 46	1
23/01/2004	51	45 46	45 56	62 47.5	1
23/01/2004	52	45 57	45 47	62 49	0
Total					410

Table 3. Number of pups counted on north-south transects during visual surveys of Northumberland Strait flown on 30 January. Transect spacing was 1 minute of longitude.

Transect	Latitude start deg/min	Latitude stop deg/min	Longitude deg/min	Total count
1	45 42	45 47	61 29	7
2	45 54	45 42	61 30	8
3	45 42	45 55	61 31	15
4	45 42	46 00	61 32	98
5	46 01	45 41	61 33	95
6	45 42	46 00	61 34	33
7	45 41	46 00	61 35	23
8	46 04	45 40	62 36	17
9	46 02	45 44	61 37	53
10	46 03	45 40	61 38	32
11	45 44	46 00	61 39	16
12	45 41	46 03	61 40	25
13	46 00	45 43	61 41	45
14	45 40	46 00	61 42	51
15	45 44	46 00	61 43	16
16	46 02	45 43	61 44	33
17	45 43	46 01	61 45	41
18	46 00	45 44	61 46	63
19	46 00	45 44	61 47	11
20	45 39	46 00	61 48	4
21	45 45	46 00	61 49	46
22	45 45	46 00	61 50	29
23	46 00	45 47	61 51	7
24	46 00	45 42	61 52	47
25	45 51	46 00	61 53	25
26	46 00	45 52	61 54	16
27	46 00	45 53	61 55	8
28	45 53	46 00	61 56	2
29	45 53	46 00	61 57	5
30	45 53	46 00	61 58	6
31	46 00	45 52	61 59	1
32	45 57	45 51	62 00	11
Total				889

Table 4. Number of pups counted on east-west transects during visual surveys of Northumberland Strait flown on 2 February. Transect spacing was 2 minutes of latitude. Longitude represents the transect endpoints.

Transect	**Latitude deg/min**	**Longitude deg/min**	**Longitude deg/min**	**Total count**
1	46 20	61 16	61 41	0
2	46 18	61 42	61 15	5
7	46 16	61 43	61 16	5
3	46 14	61 19	61 40	4
5	46 12	61 23	61 30	14
4	46 10	61 40	61 22	6
8	46 08	61 27	61 40	2
9	46 06	61 40	61 28	8
10	46 04	61 30	61 40	18
11	46 02	61 40	61 33	15
12	46 00	61 16	61 41	0
Total				77

Table 5. Number of pups counted on islands in the southern Gulf of St. Lawrence and along the Nova Scotia Eastern Shore and estimated proportion present, (SE).

Date	Location	Count	Proportion present	Corrected count
12 January	Amet Is.	230	0.58 (0.049)	396.5 (45)
24 January	Henry Is.	100	0.97 (0.042)	103 (45)
28 January	Hay Is.	2413 (75.7)		2413 (75.7)
30 January	Deadman Is.	237 (12.7)		237 (12.7)
3 February	White Is.	51		52
	Camp Island	4		4
Total		3036		3204 (76.8)

Table 6. Estimates of Non-Sable or Gulf grey seal pup production, from mark-recapture (M-R) and aerial surveys, rounded to the nearest 100. Standard errors are in brackets.

Year	Anticosti	M-R[1]	Sable	M-R[1]	Within season M-R study[2]	Aerial survey
1984	7,000 (1,200)		7,400 (1,400)			
1985	6,400 (900)		7,800 (1,700)			
1986	5,400 (700)		8,600 (2,800)			
1989	10,400 (3,200)		8,900 (2,100)		9,800 (1,000)	
1990	9,200 (2,700)		8,100 (900)		10,500(1,000)	
1996[3]						11,100 (1,300)
1997[3]						7,300 (800)
2000[3]						6,100 (900)
2004						15,900 (1,200)

[1] Hammill et al. 1998
[2] Myers et al. 1997
[3] Hammill et al. submitted.

Table 7. Estimated proportion of pups (SE) on the ice using the discrete model approach developed by Bowen et al. (2003). In this approach the stage data is tested for fit to three different distributions, the log-logistic, Gamma and Weinbull. The distribution having the largest log-likelihood ratio is retained as the best fit. The start date for pupping was 7 January for Henry Island and animals breeding on the ice.

Colony	Model	Shape	Rate	Prop born	Log-Likelihood
Henry	Log-Logistic	7.87(4.67)	0.101(0.004)	0.986(0.122)	-138.74
	Gamma	16.01(14.12)	1.59(1.459)	0.991(0.088)	-144.43
	Weibull	5.25(2.95)	10.85(0.626)	0.999(0.023)	-139.13
Ice	Log-Logistic	4.03(0.801)	0.090(.008)		-3565.58
	Gamma	6.21(2.09)	0.530(.237)		-3557.45
	Weibull	2.70(0.43)	13.05(1.40)		-3593.85
		Prop Jan 23	Prop Jan 31	Prop Feb 2	
	Log-Logistic	0.815 (0.077)	0.957 (0.029)	0.969 (0.023)	
	Gamma	0.829 (0.087)	0.984 (0.016)	0.992 (0.010)	
	Weibull	0.823 (0.109)	0.994 (0.010)	0.998 (0.004)	

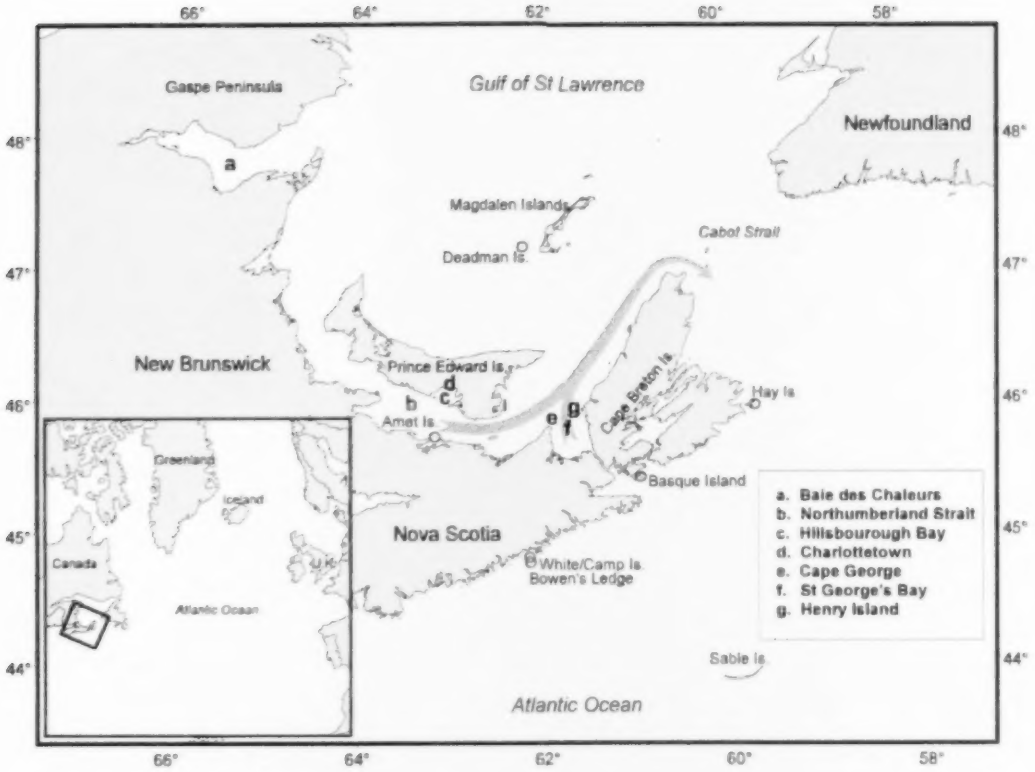

Figure 1. Location of whelping grey seals on the ice in the southern Gulf of St Lawrence. The large arrow outlines the main pupping area and direction of ice drift during the survey period.

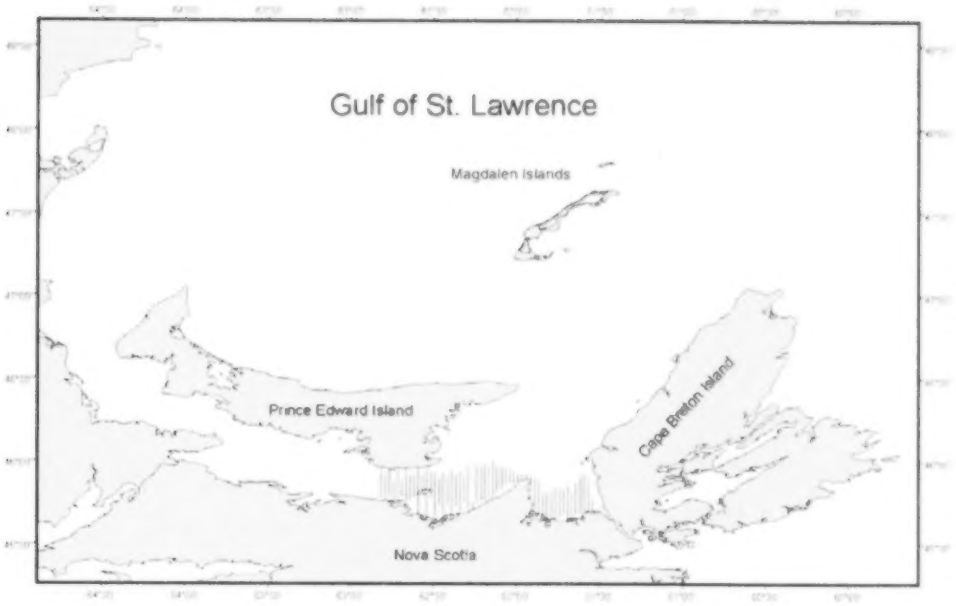

Figure 2. Location of transect lines from surveys flown 21, 22 and 23 January. Lines have been corrected for drifting ice, based on the movements of VHF transmitters placed on the ice.

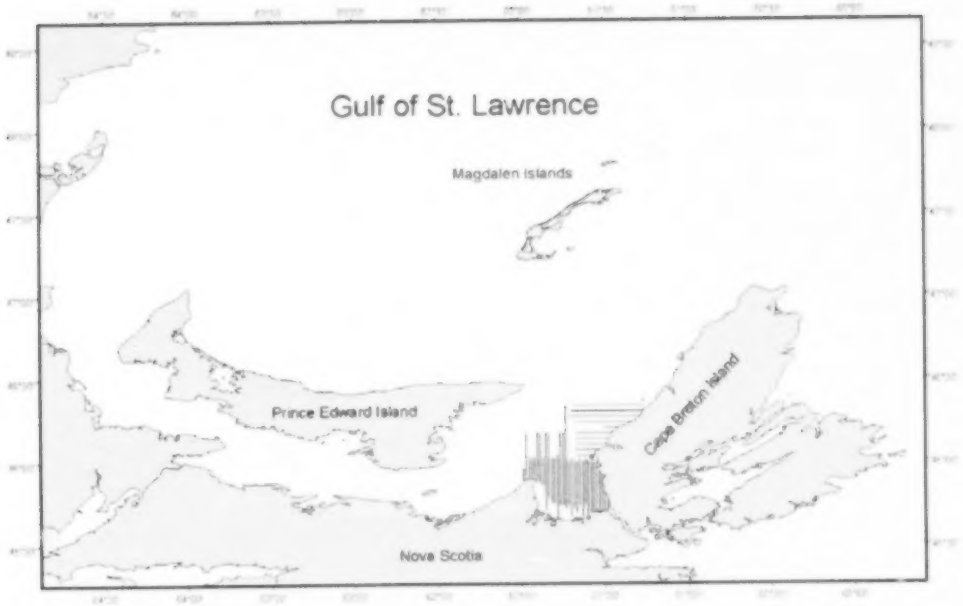

Figure 3. Location of transect lines from surveys flown 30,31 January (north-south lines) and 2 February (east-west lines).